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RESEARCH PAPER

Successful strategic breeding plan for small ruminants in Middle East: Case of Awassi sheep and Shami goat of Jordan

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Abstract

Small ruminants, particularly sheep and goats, are integral to the agricultural and socio-economic landscapes of the Middle East. Strategic breeding plans have emerged as crucial tools to enhance productivity, resilience, and profitability of small ruminant systems in arid and semi-arid regions. This article outlines the successes achieved through these breeding strategies, focusing on genetic improvement, adaptation to harsh environments, and sustainability in Jordan. Case studies and empirical findings highlight progress in genetic resource management, breeding program implementation, and capacity building. Jordan's small ruminant sector—dominated by Awassi sheep and Baladi (Local) and Shami (Damascus) goats—is vital to rural livelihoods, food security, and cultural heritage. The outcomes showed breed diversity, genetic structure, and improvement strategies, highlighting challenges and proposing a strategic roadmap encompassing conservation, genomic tools, community-based breeding programs (CBBPs), and institutional coordination. Jordan's small ruminant sector offers immense genetic potential but requires formalization and integration of advanced breeding approaches. It is recommended that strategic plan combining breed conservation, genomic-enabled selection, CBBPs, smart and reproductive technologies, institutional frameworks, and capacity building to drive sustainable improvements in productivity, resilience, and livelihood of farmers.

Keywords

Awassi sheep, Breeding program, genetic improvement, Shami goat, smallholder farming

Introduction

The Middle East is home to diverse small ruminant (SR) breeds adapted to a wide range of environmental conditions (Meydan et al. 2024). Jordan's small ruminant sector—anchored by Awassi sheep and Baladi and Shami goats—exhibits significant genetic diversity vital for resilience to arid conditions. Given the increasing demand for animal protein and the impacts of climate change, strategic breeding plans have been essential to enhance productivity and ensure food security (FAO 2020). These plans incorporate modern technologies, genetic evaluation tools, and community-based breeding programs (CBPPs) to improve performance traits while conserving genetic diversity (Thénard et al. 2024).

However, genetic improvement is constrained by informal breeding, weak recording systems, and limited biotechnological application in Jordan (FAO 2012; Al-Atiyat et al. 2021). Furthermore, SR production is constrained by declining genetic diversity, poor reproductive efficiency, disease infestation, feed and water scarcity, and weak institutional breeding programs. Therefore, a comprehensive

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strategic breeding framework emphasizing breed characterization, genomic selection, community-based approaches, and institutional coordination to sustainably enhance resilience and productivity is a sole choice and recommended (FAO 2010). Bearing in mind, community-based breeding programs (CBBPs) including improved data-management tools, and reproductive technologies and genetic and socioeconomic gains is also recommended across dryland systems in the Middle East (Haile et al. 2023). Palestine, Egypt, and the wider Central and West Asia, and North Africa (CWANA) region have practiced CBBPs at various levels and for various breeds, focusing on integrated planning, participatory farmer engagement, and the use of digital tools (Mueller et al. 2015).

This study synthesizes existing genetic diversity studies, case studies and empirical findings which highlight the necessity for targeted conservation and proposes SR strategic plan in Jordan. In addition, propose successful CBBPs of sustainable genetic improvement via modern technologies for Awassi sheep and Shami goats.

Methodology

A Strength, Weakness, Opportunities, and Threats (SWOT) survey was executed with collaboration with IFAD projects for establishment of CBBPs. The methodology followed the recommended procedure by FAO (2012). Along with SWOT survey execution, a questionnaire was also developed and executed for collecting information about Awassi sheep flocks and Shami herds location, characteristics, structure, and holder demographic characteristics. The field work and survey were executed in accordance and collaboration with field teams of Small Ruminants Investment and Graduating Households (SIGHT) project in each governorate utilizing Sheep flock book provided by the Ministry of Agriculture of Jordan (MOAJ). The shepherds, who were rearing pure Awassi of more than 50 heads and Shami goat of more than 20 heads, were randomly selected according to a stratified random sample procedure from all governorates of Jordan, to randomly and fairly represent the sheep population. More details on methodology procedure can be found by (Al-Atiyat et al. 2021). The farmers who participated in this SWOT survey were 396 sheep farmers and 55 Shami goat farmers. The weakness includes questions about infrastructure, funding, and coordination among stakeholders. Opportunities were also investigated considering farmer knowledge, training, institutional support, data recording systems, and fostering regional collaboration, investment in genetic gain and potential innovation. The SAS statistical procedures were utilized for the descriptive analysis (SAS 1999).

All work for this research of handling animals was performed with the permission of and in accordance with the guidelines set by the Ethics Committee of animal welfare, regulation 2010, Ministry of Agriculture (MOA)-Jordan (Project No.:2000001478). The permission of publication of MOA is authorized under (ID:17961; Dated 3/12/2023).

Results and discussion

Characterization of production systems

According to the 2025 Department of Statistics report, Jordan had approximately 3.076 million sheep of all breeds and 880 000 goats of all breeds in 2024, a 1% and 4% rise over the previous year, respectively (DOP 2024). Particularly, the Awassi sheep, and Shami goats are intrinsic to Jordan's cultural culinary staples (notably Dried Yogurt; Jameed by Awassi sheep and White Cheese by Shami goat) the core ingredients in main traditional cuisine and food (NARC 2021). Table 1 shows the statistics of the flocks and herds in all governorates of Jordan. Our results show that extensive systems (nomadic) represent 31.9%, with semi-extensive (partial grazing and supplementary feed) represents 18.73, and intensive fattening represents 49.37%. These figures are the survey outcomes of participating 398 farmers who were registered in sheep flock book of MOA in Jordan governorates (Table 1). Although, national reports and records stats that semi-extensive systems host 45–70% of sheep, with extensive ~20–30%, and

Table 1. Distribution of sheep holders' and flock characteristics of the survey.

Governorate	Ajlun	Amman	Balqa	Gour	Irbed	Jerash	Karak	Maan	Madaba	Mafraq	Tafelah	Zarqa	Overall
N	7	82	12	24	30	5	44	28	24	94	21	27	398
%	1.76	20.6	3.02	6.03	7.54	1.26	11.06	7.04	6.03	23.62	5.28	6.78	
Gender P-value													*0.12*
Female ownership	0	2.44	8.33	0	3.33	0	0	7.14	0	9.57	0	0	3.77
Housing type P-value													*< 0.0001*
Extensive	0	62.03	16.67	29.17	16.67	100	6.82	10.71	4.17	39.36	19.05	37.04	31.9
Intensive	100	36.71	83.33	58.33	83.33	0	86.36	10.71	75	29.79	80.95	22.22	49.37
Semi-extensive	0	1.27	0	12.5	0	0	6.82	78.57	20.83	30.85	0	40.74	18.73
Flock size P-value													*0.0016*
<150	42.86	10.98	41.67	25	20	0	38.64	14.29	8.33	31.91	23.81	11.11	22.61
150–350	28.57	37.8	50	41.67	46.67	60	31.82	50	16.67	35.11	28.57	40.74	37.19
>350	28.57	51.22	8.33	33.33	33.33	40	29.55	35.71	75	32.98	47.62	48.15	40.2

intensive fattening only ~10% (DOP 2024). On the other side, Shami goats thrive across intensive and semi-extensive systems, offering good milk yield, limited meat and beauty kids or Muzaianah that is important in the livestock shows in the Arabian Gulf area where bucks are exhibited and judged (Table 2).

Table 2. Distribution of goat holders and herds characteristics.

	Frequency	Percent
Ownership		
Institutes	2	3.64
Female ownership	2	3.64
Male ownership	51	92.73
Governorate		
Ajlun	5	9.09
Amman	3	5.45
Balqa	10	18.18
Irbed	4	7.27
Jerash	4	7.27
Karak	1	1.82
Madaba	10	18.18
Mafraq	13	23.64
Zarqa	5	9.09
Production System		
Intensive	33	60
Semi extensive	22	40
Herd size		
<150	42	76.36
150–350	10	18.18
>350	3	5.45

It was noted that the population size dominated was by big holders for sheep and goat, respectively. The holders were in most governorates (such as Balqa, Madaba and Mafraq for goat and Amman, Jerash, Madaba, Mafraq, Tafelah, Zarqa). The results are like previous reports stating that the smallholder is usually owned by less than 100 sheep/goats. A typical farm owned 100–500 sheep/goats in all governorates except Mafraq often exceeding 500 head (Awad et al. 2024).

In fact, current persisted feed and water scarcity are enforcing farmers towards intensives system and reducing their holding sizes. This was reported by farmers surveyed and official stakeholders of MOA. Currently, both species are blending limited feed and water, high heat and drought resilience with moderate milk and lamb/kid-crop performance. Climate change (projected 15–25% precipitation decline) have dramatically reduced vegetative cover in the Jordanian range land (Badia), resulting in widespread overgrazing (Abdulla 2020). Jordan ranks among the world's most water-scarce countries, intensifying pressure on livestock farming via feed and water shortages (Nagle-Alverio et al. 2024). It is worth saying that feeds and feeding for small ruminant in Jordan is dominated by thicker barley-straw feeding and graze residues, especially in nomadic compared to intensive system. Supplementation with vitamins and minerals doubled chances of twinning and improved lamb survival (Abdulkareem et al. 2023). Furthermore, the results revealed that most holders used mixed crop-livestock systems; most obtained their breeding stock via on-farm sources and most of holders had primary education or less.

The government runs feed subsidy program that offers barley/wheat bran subsidies to SR holders, thus keep animals surviving all year long. It is worth mentioning that SR production in Jordan plays a dual role: supporting national food security and sustaining rural economies in rural regions. While livestock accounts for only ~1.8% of the Jordanian workforce, it contributes to ~4% of GDP, with small ruminants making up nearly one-third of total herd size (DOS 2024). Jordan's agricultural policies prioritize self-sufficiency in animal-source foods; as of 2023–24, the country attains ~30% of red-meat demand domestically, with ~1% annual growth in sheep and goat stocks (DOS 2024).

Characterization breeds and breeding systems

Awassi sheep

The results showed that predominant sheep breed is the indigenous Awassi sheep (Fig. 1). Some other imported sheep breeds such as Assaf and Chios are available in few hundreds, whereas Charollais, Romanov, Suffolk are available in few numbers. Though, Awassi accounts for >90% of the national flocks. It is fat-tailed, dual-purpose (milk, meat, wool) and boasting high environmental tolerance. Nevertheless, Awassi sheep is classified into three strains (Ecotypes); Baladi, Naemi and Saqri (Al-Atiyat et al. 2021).

Awassi ewe yields 120–150 Liter during lactation period over 150 days under traditional systems; improved lines deliver up extra to 70–80 kg of milk per 150-day season. In specific, average milk yield is ~133 kg, daily yield is 100–900 mL, peak ~0.8 kg/day. Heritability estimates ~0.26–0.27, indicating moderate response to selection. The ewe reproductive cycle details are puberty at 9 months, estrous cycle lasts 15–20-day, gestation lasts 152 days, weaning at 90 days of lamb age, and breeding time in April to September (Meydan et al. 2024).

Genetic studies show the Awassi's intra-population diversity is substantial. Al-Atiyat et al. (2014) sampled 294 sheep from ten regions, reporting average alleles per locus of 12.67, He = 0.82, Ho = 0.684. The studies showed significant geographic structuring among regional and Arabian Awassi populations. It has its own genetic clade, though exhibits historical gene flow with neighboring Najdi and Naemi populations (Al-Atiyat et al. 2014; Al-Atiyat et al. 2018). These findings stress both the rich genetic diversity within Awassi and the need to genetically utilize their local strains/ecotypes in Jordan, considering establishing a foundation for genomic selection with whole-genome resequencing recently reported (Haddad et al. 2020).

Figure 1. Different body morphology, horn shape and head color of Awassi sheep (Mature Rams above and Mature Ewes below).

Goat breeds

Goat breeds in Jordan are dominated by the Baladi (Mountain Black) type, supplemented by Desert, Black Bedouin (Dihawi), Shami (Damascus) goats, and as well as crossbreds of all of them (Zaitoun et al. 2005). The Shami goats, main interest of the study, represent ~3% of total population. As of current survey, more than 50% of the population is in Central governorates (Balqa, Amman, Madaba and Zarqa). The result findings were like the previous reports showing ~85–90% of the goat population in Mafraq, Amman, Irbid, Madaba and Balqa (Zaitoun et al. 2005).

Shami goat forms a diverse phenotypic and genetic base with substantial imported sources in current days (Fig. 2). The reports stating that Jordan Shami goats are divided into two strains: dairy and beauty goats. Current genetic characterization of Jordanian goats is limited. Informal crossbreeding among Baladi, Shami, and Desert goats likely results in admixed populations (Al-Araimi et al. 2017; Al-Atiyat 2017). Comparative phenotypic work shows that Shami goats outclass Baladi in kid growth (Al-Barakah et al. 2024), yet genomic data are lacking—representing a key research gap. In addition, goat reproduction, in general, considering smallholders data reported goat flocks had 90.6% successful birth rates, but lower kid survival in harsh winter months (Al-Barakah et al. 2024).

Figure 2. Jordan Shami goat phenotypes (yearling male, yearling female, mature doe, mature Buck, from left to right respectively).

Breeding strategies & institutional structure

Government and research stations

The Ministry of Agriculture is the official institution that govern SR breeding in Jordan. The National Center for Agricultural Research at Al-Khanasry Station, in north region, has led Awassi genetic improvement since the 1970s. Key steps included initiation of selection using Estimated Breeding Value (EBV) and performing feeding studies (NARC 2021, 2025). Furthermore, Al-Fjaij Station is another Awassi breeding station in the Southern of Jordan. The breeding practices is limited in the station and receives genetically improved Awassi rams from Al-Khanasry Station, playing a role of Multiplication and distribution to farmers. In both Stations, annual distribution of improved rams was reported to farmers (FAO 2015; NARC 2021). Furthermore, recent activities noted by a national project known as a Small Ruminants Investment and Graduating Households (SIGHT) Project targeted distribution of rams to the Elite farmers and well-trained smallholder households on herd management, breeding and feeding.

Shami goats are reared in a station named Al-Wala. The station is considered only a breeding premises for Shami goats in Central region of Jordan. There is a small herd for research purposes at Mutah university in Southern region. The herd of Al-Walah was established in 1990s by breeding stock of Cyprus Shami goat and subjected to recent importing more few hundreds breeding bucks and does from Cyprus.

Strategic breeding approaches

Strategic Breeding approach is well known to worldwide specialists as a best approach for national animal breeding program. It includes selective breeding and/or crossbreeding, and/or genomic selection. Selective breeding within local breeds has improved traits such as milk yield, growth rate, and disease resistance (Galal 2008). Crossbreeding programs were focusing on introgression and implemented to combine the adaptability of local breeds with the productivity of exotic ones, notably in countries like Jordan, Iran, and Egypt (Leroy et al. 2016). Genomic selection, although in its infancy in Jordan and the region, offers promising potential for accelerating genetic gains (Mrode et al. 2018).

Furthermore, Community-Based Breeding Programs (CBBPs) model is also well known and recommended by animal breeders and specialist (Kosgey and Okeyo 2007; Mueller et al. 2015; ICARDA–CEVA 2017). It empowers farmers to select breeding stock from pooled flocks, record performance, and make collective sire choices. Initially, CBBPs is treated as being based on an internationally recognized program that relies on a genetic selection strategy and follows the Open Nucleus Breeding Program (ONBP) (FAO 2010). The ONBP provides use and investment of genetic resources of animals (Awassi sheep and Shami goats) which genetically evaluated and characterized. The development of ONBPs for Awassi sheep (Al-Khanasry and Al-Fujaij) and Shami goat (Al-Wala) stations in Jordan requires first a big umbrella which is the Strategic Breeding plan. The successful CBBPs and ONBP is based on drives sustained genetic gains in low-input settings with avoiding inbreeding and preserves locally adapted genetic makeup. Some successful CBBPs were

reported in neighboring regions. For example, in Africa, CBBPs have delivered average income increase of 20%, formation of cooperatives, and national adoption with donor support (Mueller et al. 2015).

In Jordan, CBBPs for the Awassi sheep and Shami goats are not practiced so far. It might be assumed to lead to significant improvements in milk production and reproductive performance that ends up with increasing meat yield. This assumption was driving force of the current SWOT case study. The farmers of both species stated their preferred breeding objectives as shown in Table 3.

Table 3. Proportion of recommended breeding objectives for Awassi sheep and Shami goat farmers.

Number	Milk production	Meat production	Disease resistance	Adaptability to environment	Strain unique morphology	Fiber production
Awassi sheep (P-value < 0.001)						
396	388	346	360	348	325	80
	97.98	87.37	90.91	87.88	82.07	20.20
Shami goat (P-value < 0.001)						
55	51	34	54	53	51	1
%	92.73	61.82	98.18	96.36	92.73	1.82

SWOT of Awassi sheep and Shami goat industry

Strength

The SWOT analysis considered in this study reported that the main strength points were pastoralists who consider livestock as only source of livelihood (Table 4). Furthermore, most Smallholder were practicing the livestock-crop integration model across rain fed and Badia regions. They were producers with good experience in animal health, winter housing, kid/lamb mortality reduction, feeding concentrates and supplements such as vitamin/selenium supplementation and proper ram replacement practices as well as in vegetating crops (Titi et al. 2008).

The weakness

The major weakness was feed scarcity, which resulted from water scarcity. In fact, the reported weakness is somehow related to environmental stressors and persisted climate change that face livestock industry in Jordan. The sheep and goat holders reported a need of more capacity building in livestock-crop integration and water harvesting practices to overcome feed and water scarcity problems. They also pointed out that more weakness comes from weak market structure and broken value chain for selling lambs and wool, mainly. Similarly, the findings of Al-Barakeh et al. (2024) and Titi et al. (2023).

In addition, they reported that low use of reproductive technologies, poor record-keeping, risk of genetic dilution, limited knowledge of goat genomic resources and fragmented breeding programs. The latter emphasizes breeding and genetic improvement where many programs remain in early stages without scale-up and with low sustainability. Sustained impact requires stable policy frameworks and backing beyond pilot phases. It was related to capacity constraints, trained personnel and limited access to genomic infrastructure, and low implementation of advanced genetic tools. Finally, they stated that previous genetic improvement program did not integrate traits such as heat tolerance, disease resistance, and feed efficiency for resilient breed improvement. Weaknesses have been reported for appropriate organizational, legal, and legislative structures that regulate the genetic improvement process and activate the direct participation of breeders through the establishment of a genetic improvement unit. In addition to non-availability of specialized genetic improvement associations in a cooperative system, based on internationally recognized genetic improvement organizations.

The opportunities

The results showed that the suggest Jordanian CBBPs' opportunities lie in following opportunities (Table 4). They are presence of infrastructure (stations, employees, and records) availability of capacity-building programs and training for genetic improvement specialists, availability of reports and studies of genetic and genomic work of Awassi sheep and Shami goat using, for example SNP and microsatellite DNA markers.

The holders emphasized the importance of localization of breeds and objectives—focusing on indigenous breeds (Awassi, Shami)—to ensure resilience in arid conditions, rather than unsuited exotic hybrids. It was reported that genomic and phenotypic studies on goats demonstrate high genetic diversity (Al-Atiyat et al. 2014, 2018, 2021), and thus opportunity for structured selection within Open-nucleus breeding design programs (ONBP) and genomic marker application are being proposed to accelerate gains in heat stress resilience and prolificacy, aligning with their recommended breeding objectives.

The participants pointed out that implementing genetic improvement using data management systems including selection indices and estimating all possible parameters for economic traits could be a good opportunity. Availability of a system with digital Data Management and softwares was reported (SIGHT-IFAD reports) which EBV-based selection and apply genomic evaluations (IFAD 2020). Enhanced Genetic Selection Methods with expand pedigree-based and genomic selection was mentioned by farmers of Awassi sheep and goats, which is limited so far for Shami (Al-Araimi et al. 2025). In regards, introduce heat-tolerant genotypes, especially for desert-adapted Shami goat populations might be intervention opportunity.

Particularly, the digital system of recording is available which enables real-time genetic data reporting, genetic evaluation, culling of unproductive animals, and more

precise selection decisions. In addition, different breeding and genetic softwares are made available for breeding stations by IFAD projects and professional scientists. The international collaboration of MOA and international organizations (e.g ICARDA) made programs like DTREO available for small ruminant breeding by enabling transparent, science-based management at the smallholder level (ICARDA 2024).

The availability of reproductive technologies and training is another opportunity reported. Reproductive technologies—including estrus synchronization and artificial insemination (AI) with elite sires—have been integrated into national programs, such as elite Awassi sheep nucleus flocks at NARC (Jordan), combined with farmer-level tenure via elite semen deployment and training of veterinarians in private sector through ICARDA–CEVA initiatives (ICARDA–CEVA 2017). If AI capacities expanded; embryo transfer for elite ewes to multiply high-merit lines might be considered.

Finally, farmer participation and ownership are a key opportunity to CBBPs success. Involving farmers from the outset in defining selection traits, pooling flocks, and making breeding decisions ensures sustainability. Integrated capacity building for farmers combining technical training on genetics and nutrition and reproduction such as promoting estrus synchronization and using controlled mating to maintain breed purity, strengthens field veterinarians and extension agents. Market enhancement and constructive value chain are needed considering geographical indication to retrieve price premiums and modernize and digitalize marketing windows. The recent attempt of quality-graded wool cooperatives for Awassi wool exportation could be considered another opportunity for SR strategic plan. Since Awassi sheep wool of Jordan with good quality as a carpet wool (Tabbaa et al. 1998, 2001).

Threats

In addition to feed scarcity and limited feed subsidiary system, the main reported threat was marketing and unstable milk prices that is governed by monopolization of large-scale dairy sector, which has been in limited support from government (Table 4). Moreover, losing institutional strengthening and policy support. The genetic improvement division in MOA and national small-ruminant

Table 4. Strengths, Weaknesses, Opportunities, and Threats (SWOT) Analysis of small ruminant breeding and genetic improvement of Awassi sheep and Shami goat.

SWOT category	SWOT factor
Strengths	• Householders were pastoralists. • Most Smallholder were practicing the livestock-crop integration system. • They inherited good experience as producers in animal health, feeding and breeding. • Breeding station infrastructure, and flock/herd structure.
Weakness	• Feed scarcity and water scarcity. • Environmental stressors and persisted climate change. • limited capacity building in livestock-crop integration and water harvesting practices. • Weakness market structure and Value Chain. • Low use of reproductive technologies. • Poor record-keeping and pedigree identification. • Risk of genetic dilution (crossbreeding). • Limited knowledge of genetic and genomic resources and breeding programs. • No policy frameworks for breeding and genetic improvement. • No integration of heat tolerance, disease resistance, and feed efficiency in breeding.
Opportunities	• Availability of capacity building of specialists for breed Characterization and evaluation. • Availability of reports and studies of genetic and genomic work of Awassi sheep and Shami goat. • Their preference of breeds localization by focusing on Jordan Awassi, and Shami and avoiding unsuited exotic hybrids. • Preference of Open-nucleus flock designs (OPN) and genomic DNA marker application. • Considering their proposed breeding objectives to accelerate genetic gains in heat stress resilience and prolificacy aligning with milk and meat yield. • Availability of digital data management system and softwares for genetic evaluation. • The availability of reproductive technologies and training. • Farmer participation and ownership. • Ability for Market Enhancement and constructive value Chain.
Threats	• Feed scarcity and limited feed subsidiary system. • Unstable marketing and unstable selling price of milk and lambs/kids. • Monopolization of large-scale dairy sector. • Losing institutional strengthening and policy support. • No genetic improvement division in MOA and national small-ruminant genetic improvement committee. • Not enough specialists and breeders. • Not enough budgets for on-station nucleus flocks, genotyping, and breeding services.

genetic improvement committee, involving NARC, universities, MOA, ICARDA, donors, and farmer organizations were not activated. Animal breeding division in MOA was supposed to be responsible for tracking genetic trends, production traits, and participation rates and regularly evaluate and refine breeding strategies based on breeding outcomes. There is not enough specialists found to continue training farmers on best breeding practices nor allocate budgets for on-station nucleus flocks, genotyping, and extension services.

The recommended successful strategic plan

As per stated results, we recommended successful strategic plan in the context below. The Plan should have a vision stated as a sustainable, productive, and resilient small ruminant sector in Jordan that enhances rural livelihoods, food security, and genetic biodiversity. It is mission would be to improve the productivity and profitability of Awassi sheep and Shami goat farming through CBBPs, sustainable feeding systems, enhanced animal health, and strong market linkages. Therefore, the recommended strategic objectives are outlined in Table 5. The recommended successful strategic Plan should have timeline of 5-year period (2025- The plan needs Implementation 2030). The Implementation timeline milestones include launch and start CBBPs and pilot rangeland projects in first year, expand vaccination and genetic recording in the second year, establish cryopreservation bank and breed certification in third year, scale marketing cooperatives and feed interventions in the fourth year and finally evaluate and adapt plan with dissemination of elite ewes and rams.

Table shows objectives of the plan win which first objective is establishing as national genetic improvement program for small ruminants including other goat breeds. It is good to note that other Jordanian goat breeds apart from Shami have no breeding station, thus it is advisable to establish stations for their genetic seed stock to have them into genetic improvement program. Again, CBBPs for sheep (Awassi) and goats (Shami) as detailed in Table 5 and previously stated in opportunity section shall apply digitize performance and pedigree recording, EBV-based selection indices and genomic evaluations using SNP panels, AI and embryo transfer for elite rams and ewes, respectively to multiply high-merit lines.

Table 5. Recommended successful strategic breeding plan of Small Ruminant of Jordan with actions and key performance indicators.

Objective	Action	Key Performance Indicators (KPIs)
CBBPs; Genetic Improvement with purity Conservation	• Develop community-based breeding programs (CBBPs) for sheep (Awassi) and goats (Shami) of five-year period (2025–2030). • Consider the CBBPs as national genetic improvement Program for small ruminants (currently for both species). • Implement performance recording and genetic evaluation of key traits (milk yield, growth, fertility, disease resistance). • Establish gene banks and cryopreservation facilities for local breeds. • Regulate and monitor crossbreeding practices to avoid genetic dilution.	• Annual productivity increase (milk/lambs per ewe) of 20%. • % of Elite farmers using improved rams/bucks of >50%.
Sustainable Feeding Systems	• Promote forage crop cultivation and feed blocks using agricultural by-products. • Support Rangeland rehabilitation programs with water harvesting and reseeding. • Develop feed budgeting tools and farmer training on optimal nutrition.	Increasing area of rehabilitated rangeland by 30,000 hectares.
Animal Health and Biosecurity	• Strengthen veterinary extension services with mobile health units in remote areas. • Implement vaccination programs for PPR, brucellosis, and enterotoxaemia. • Establish disease surveillance systems and early warning mechanisms. • Train farmers on biosecurity and preventive health measures.	Reduce prevalence of major diseases by 70%.
Market Access and Value Chain Development	• Create producer cooperatives to aggregate products and improve bargaining power. • Develop branding and certification for products from local breeds (e.g., Awassi lamb). • Invest in cold chain infrastructure and modern slaughterhouses. • Facilitate access to regional and export markets (e.g., Gulf countries).	• Increasing products sold by 40%.
Capacity Building and Research	• Train breeders, extension agents, and veterinarians on modern breeding and animal husbandry. • Partner with Jordanian universities and international research centers (ICARDA, FAO, etc.). • Support on-farm trials and adaptive research on breeding and feeding strategies.	• Activate breeding division. • increase number of specialists by 2 every year. • Cryopreserved local breed by 5,000 samples.
Policy and Institutional Support	• Develop a Small Ruminant Breeding Policy Framework aligned with Jordan's National Agricultural Strategy. • Provide incentives and subsidies for participation in genetic improvement programs. • Promote public-private partnerships (PPPs) in breeding and marketing.	• SR Breeding Fund establishment and include National Government Funding (Ministry of Agriculture). • International Donors (FAO, IFAD, USAID, EU). • Private Sector Investment. • SR holder corporation/association.

To achieve remaining objectives, sustainable feeding strategies of range restoration and fodder system are needed to rehabilitate Badia grazing lands, control overstocking, and promote reseeding of native forage species. Encouraging livestock-crop integration to lower feed costs and stabilize supply is requested and recommended earlier (Abdullah and Titi 2007). Although some small ruminant holders have solved the feed scarcity and milk marketing problems, they had no ability to get genetically high milk producing animals. Here comes the importance of providing genetically improved ewes or does along with its training, implementation and sustainability. The disease control, postharvest and access to markets as well as policy support can be achieved as Key Performance Indicators (KPIs) stated by 2030 (Table 5). Another type of needed policy support is empowering women's role in breeding sheep and goats. IFAD (2007a) revealed that the knowledge of livestock and its management among rural women most often remains underestimated in developing countries. It is preferred as a special gender task that women mostly take part in assisting genetic characteristics and practicing breeding and genetic improvement for their sheep and goat. For example, women spend almost five hours daily in the management/control of sheep production (IFAD 2007b). Empowering those women with technics and knowledge of short time in sheep breeding practices like time of mating, selection guidelines and selection index would result in more profitable business and best income potential. Furthermore, women's role in marketing SR products using digital marketing windows is significantly noted.

Particularly, increasing SR market value opportunities were reported. First, Awassi sheep have a big international market in the Gulf countries (Saudi Arabia, Emirates, Oman, Qatar and Bahrain) as live animal for meat consumption, in one side. On the other side, Awassi sheep exported to countries such Australia and America for establishing Sheep Dairy Farms. Consequently, an international recognition of this sheep breed was made. In this regard, reaching a global market and export opportunities requiring a brand or trade name or at least achieving geographical indicator of Awassi sheep as Jordanian Awassi. Thus, increase their export opportunities and increase the economic return resulting from their marketing, which will increase the contribution of the agricultural sector to GDP of Jordan. It is important to note that, in current years, the economic value of Awassi sheep in local market in Jordan and nearing countries were increasing. The future expectation for the prices of Awassi individuals of genetically improved individuals (Rams and Ewes) is also increasing. The second of all, Shami sheep have worldwide marketing demands for its high milking ability. They also are nowadays marketed as beauty goats with high prices in comparison with dairy producing goats. The beauty-specific breeding specifications of Shami goats make it most wanted commercially.

In general, the questioned experts stated that the economic value of stud animal of both Awassi sheep and Shami goat which is fully characterized for their genotypes and phenotypes must be considered for regional market. In other words, the market selling market price of breeding rams or bucks and ewes or does would be higher than those animals sold in sale yards. In fact, brokers are encouraging farmers to produce breeding animals as genetically improved animals for export to Gulf countries. For example, many farmers shifted their efforts to raising dairy Shami goats because they have a major role in eradicating poverty towards rearing Beauty Bucks and kids. In fact, adult (<2-year-old) buck, might be sold, in current time, for milk production purposes between USD200 to USD400 in Jordan and international markets. These prices are not comparable to the price of the head of Beauty Bucks, which might reach more than 25 thousand dollars.

Successfully established CBBPs in stations

The successful CBBPs requires considering the Al-Khanasri Station as the best selected for Awassi sheep breeding. The breeding objectives of this program were those mentioned earlier by Awassi holders (Table 3). Noting, to achieve the agreed-upon those objectives, their selection criteria should pre-specified. Awassi CBBPs should have a distinctive three tier optimal breeding program design (Three tier ONBP) (Fig. 4), with feasibility outcomes (Fig. 4). The three tier ONBP include involvement of the Al-Khanasri station as genetic improvement sector (nucleus), Al-Fujaij as multiplier sector station and Elite sheep famer as the commercially production sectors. On the other hand, Al-Wala Station is the best choice for Shami goat CBBP. The breeding objectives of this program are recommended to be divided into two main objectives. The first is production of high yield dairy females and males under the intensive system. The second is production of beauty females and males traded commercially under the intensive system. Both objectives can be applied to separate herds in Al-Wala Station. The selection criteria can be arranged within the breeding program for each objective. In similar, the ONBP system consists of three tiers is recommended. Both recommended ONBP shall be Implementing over a five-year period. Another important point to highlight is the feasibly or optimism of best ONBP. For example, using simulation model of predefined breeding objectives of proposed Awassi ONBP flock of in Al-Khanasri station 2,000 heads (6% of the total improvement herd – the participating stations and breeders' herd, which is 32,700 heads) for a period of five years (Fig. 4) show good genetic gain and feasibility. The average annual genetic return will be 0.112 kg/day/year of increase in milk production (0.560 kg/day/head after five years) and 0.130 kg in market weight (0.650 kg/head after five years).

The action plan shall be developed to achieve successful completion and sustainable execution. We recommend the action plan activities mentioned in Table 5. The first activity is formulating and stating out breeding objectives based on scientific knowledge (Tabbaa and Al-Atiyat 2009). The agreed-upon objectives made by experts at the meeting held at NCAR (on Thursday, December 21, 2020) optimize milk and meat production for Awassi sheep and for local goat breeds (Black Bedouin, black Mounting and Desert) in the semi-in-

tensive system. For Shami goats, it is recommended to implement two objectives as dairy and beauty Shami goats, with each objective allocated a herd (a separate dedicated ONBP herd). Its entire herd will be the nucleus herd for each strain under the intensive production system. Nevertheless, it was recommended to establish goat ONBP in Jordan considering the production system (Al-Atiyat 2014). Furthermore, breeding values and genetic parameters are available, especially in Al-Khanasri. Awassi flock but not all needed values drawn up for comprehensive selection criteria. Meaning that selection will follow a tandem selection procedure with traits of available heritability values and EBV. It is preferable to accurately determine the breeding values to predict genetic improvement with best financial profit as optimized program.

The second activities include identifying selection groups of males and females within each station and across all stations, as well as with Elite farmers (breeders), and genetically evaluating the animals under their own production conditions. The required administrative and genetic linkage between stations and breeders, as well as between breeders themselves, shall then be established, followed up, and monitored. Adopting a selection strategy and establishing selection groups of males and females at the Al-Khanasri station, shall be based on the available EBV values, whereas they shall be based on the phenotypic and morphological evaluation traits of the startup Shami goat herd. This also applies to the herd at the Al-Fujaij station, considering the rams and ewes supplied by the Al-Khanasri station and adopting a mechanism for merging the rams within selection groups. As for breeders, since their animals have not been genetically evaluated in these locations, it was recommended that selection groups be conducted between the rams mated to them and the participating females and vice versa. This is one means of establishing the required administrative and genetic linkage between stations and breeders. Genetic linkage is achieved through the presence of shared males, whose offspring are available at all stations and with breeders, thus serving as a tool for comparison between the offspring (males and females) of all shared rams and others. This step began with the dispatch of rams from the Al-Khanasri station to the Al-Fujaij station for use this season, as well as to elite breeders (Fig. 4). It is good to emphasize avoiding inbreeding as much as possible. This is to maintain a high rate of genetic improvement.

It is recommended, for the third activity, to increase the number of genetically proven males (rams and bucks) through progeny testing and genomic evaluation. The genomically proven animals shall be sampled from breeding stations and elite partner breeders (for Awassi sheep and

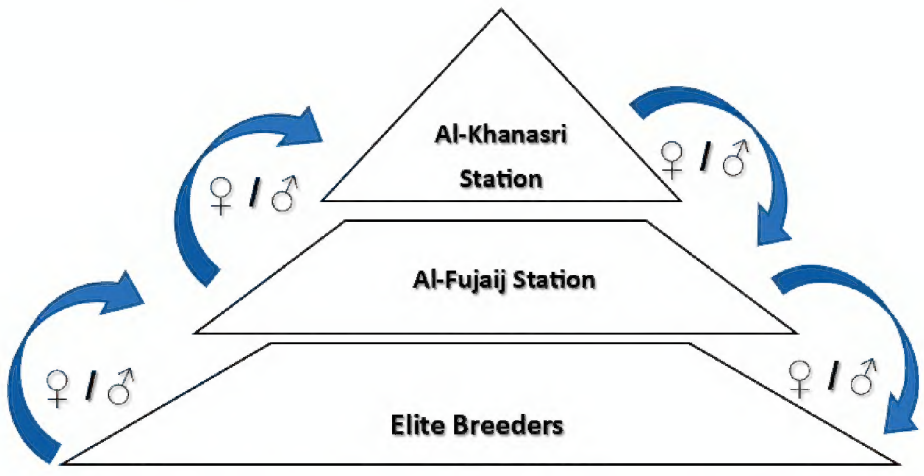

Figure 3. Proposed Scientific open nucleus breeding program (ONBP) design for Awassi sheep.

Traits

Name	Ec. value	σ(P)	Heritability	Repeatability	Herd	Litter	Random	Repro.	Unit	q	N	k	r(TI)
Birth Wt	0.0	0.82	0.31	0.7	0.1	0.2	0.0	☐	KG				
Daily gain	0.0	0.01	0.26	0.63	0.0	0.0	0.0	☐	KG				
Dam Wt	0.0	11.5	0.31	0.9	0.1	0.1	0.0	☐	KG				
Kid survival	0.0	0.05	0.4	0.83	0.0	0.0	0.0	☐	kid				
Market Wt	40.4	4.9	0.26	0.78	0.1	0.0	0.0	☐	KG				
Neonatal Mortality	0.0	0.01	0.15	0.38	0.0	0.0	0.0	☑	kid				
Partial milk	0.0	0.78	0.23	0.59	0.1	0.0	0.0	☐	KG				
Weaning Wt	0.0	0.3	0.33	0.6	0.1	0.0	0.0	☐	KG				
milk yield	8.0	4.5	0.24	0.7	0.1	0.1	0.05	☐	KG				
proficacy	0.0	0.016	0.12	0.25	0.1	0.2	0.0	☑	KG				

Genotypic Correlation Matrix

Traits	Birth Wt	Daily gain	Dam Wt	Kid survival	Market Wt	Neonatal Mortality	Partial milk	Weaning Wt	milk yield	proficacy
Birth Wt	1	0.39	0.05	0.63	0.45	0.9	-0.1	0.45	0.2	0.3
Daily gain	0.39	1	0.0	0.6	0.0	0.03	0.0	0.4	0.15	0.25
Dam Wt	0.05	0.0	1	0.73	0.54	0.1	0.15	0.0	0.05	0.0
Kid survival	0.63	0.6	0.73	1	0.72	-0.15	0.3	0.45	0.75	0.34
Market Wt	0.45	0.0	0.54	0.72	1	0.0	0.1	0.77	0.0	0.25
Neonatal Mortality	0.9	0.03	0.1	-0.15	0.0	1	0.3	0.0	0.3	0.23
Partial milk	-0.1	0.0	0.15	0.3	0.1	0.3	1	0.13	0.65	0.25
Weaning Wt	0.45	0.4	0.0	0.45	0.77	0.0	0.13	1	0.1	0.42
milk yield	0.2	0.15	0.05	0.75	0.0	0.3	0.65	0.1	1	0.62
proficacy	0.3	0.25	0.0	0.34	0.25	0.23	0.25	0.42	0.62	1

Genetic Gain per Time Unit	
Market Wt	0.13051
milk yield	0.11256

Figure 4. Simulated ONBP scenario of Awassi breeding flock of 2,000 heads (6% of the total improvement herd – the participating stations and breeders' herd, which is 32,700 heads) for a period of five years.

Shami goats) for evaluation and selection of parents for the next generation. The selection index (SI) will be prepared based on calculation of the genomic Estimated Breeding Values (G-EBVs). The G-EBVs will be prepared annually with an index of possible evaluated selection criteria. The selection index will be developed in the improvement process to achieve balanced improvement in breeding objectives. This will be achieved by retaining animals that carry the highest possible index value. This index will be developed at the Al-Khanasri station for Awassi sheep and Shami goats after providing data from the Al-Fujaij and Al-Wala stations and elite breeders, using one of the specialized programs recommended by us or any of the approved ones. The fourth activity will include application of AI should be performed using semen of improved elite rams with the highest SI and high breeding values at the stations or with breeders. In parallel way, implementation of embryo transfer is recommended for the highest SI ewes. The last activity would be establishing SR breeding association of selected elite breeders from across the Kingdom. The goal of SR breeding association is to manage and sustain the operation, ensuring best genetic resources management of CBBPs with ONBP. This requires the establishment of a specialized technical unit (division) for genetic improvement management in the MOA.

Conclusions

The Awassi sheep and goat remain fundamental to rural resilience and national identity. However, the sustainability of this system faces mounting risks from climate stress, land degradation, feed scarcity, and limited marketing commercial incentives. Addressing these requires a combination of genetic improvement throughout genomic selection, rangeland restoration, value-chain formalization, and climate-smart extension services. Such procedures are addressed within the recommended strategic breeding plan based CBBP which help Jordan progress toward self-sufficiency in red meat, rural poverty reduction, and continued vibrancy of its pastoral heritage. SR CBBPs are anchored by community-based models, reproductive technologies, and data-driven tools—has begun yielding tangible improvements in productivity and incomes. Key successes include CBBPs delivering measurable genetic gains and profit. Future efforts should integrate genomic selection, continue farmer engagement, strengthen institutions, and scale successful pilots to national systems to safeguard indigenous small ruminants and livelihoods. Continued governmental support for these programs, along with technological adoption and policy integration and support, will ensure sustainable CBBPs. In addition, it might be recommended applying climate-smart feed and water mitigation strategies, electronic tracking and artificial intelligence applications. Empowering women holders with technics and knowledge of SR breeding practices like mating and selection guidelines and selection index would result in more profitable business and best income potential for their household.

Author contributions

Raed M. Al-Atiyat: Conceptualization, data curation, investigation, methodology, supervision, writing original draft and editing. Mohammad J. Tabbaa: Conceptualization, formal analysis, investigation, methodology, Validation, and writing, review and editing. Faisal S. Barakeh: Conceptualization, data curation, funding acquisition, investigation, project administration, supervision, validation, visualization, writing.

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